Pilot Project of Elgaugol Active and Adaptive Grid Cluster: Development Objectives and Key Engineering Solutions

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One of the most important directions of electric power industry modernization and innovative development is the construction of smart energy systems with active and adaptive grid (SES AAG).

Smart energy system (Smart Grid) is, in fact, a new phase in the electric power systems development in the 21st century.

The Institute of Electrical and Electronics Engineers (IEEE) defines a Smart Grid as a fully integrated, self-adjusting and self-recovering electric power system with a network topology, which comprises all generation sources, main and distribution networks and all types of electric power consumers, controlled by a common network of information controllers and systems in real-time mode.

**Smart (active and adaptive) grid** is a brand new type of electric power grid which allows real-time monitoring and control of the grid, setting communications between consumers and suppliers, providing the possibility of consumption optimization, reducing the cost of electric power and, therefore, ensuring a new level of power supply reliability and cost efficiency.

Under the auspices of the Russian Federation Government, FGC UES has started a large-scale pilot project of a smart energy system with an active and adaptive grid on the base of Eastern United Energy System.

Project specifications can be found at the website of FGC UES:

The first in Russia cluster of active and adaptive grid Elgaugol, with a technological platform for active and adaptive control model implementation based on the solutions by the leading Russian and international manufacturers, will be the first result of this project.

NOVINTECH is in charge of management and implementation of the pilot project of Elgaugol AAG territorial cluster development, as it has a great experience in systematic integration and introduction of new equipment by Russian and international manufacturers.

- The tasks of NOVINTECH consist in the design development and implementation of AAG smart loops at the cluster facilities, including:
  - Development of key engineering solutions of the project;
  - Design development;
  - Testing of compatibility of equipment by different manufacturers in accordance with IEC 61850;
  - Comprehensive bench tests of equipment;
  - Equipment supply to the cluster facilities;
  - Putting equipment into trial operation.

At present, key engineering solutions for new substations and power transmission lines have been approved, and designs of primary and secondary equipment are being developed.

Elgaugol AAG cluster creation will be a base for practical implementation of new technologies and engineering solutions which could afterwards be used in new projects of smart grid construction in Russia.

**Brief Specifications of Elgaugol Cluster**

For electric power supply to Elga Coal Production Complex, three 220 kV substations will be built: Elgaugol, A and B, as well as two 220 kV power transmission lines, each 268 km long, including a special crossing over the Zeyskoye water reservoir. Moreover, existing Prizeyskaya 220 kV Substation will be reconstructed.

Electric power supply system of Elga Coal Production Complex will be built in two phases. By the end of 2012, FGC UES will create the conditions for the electric power supply to the complex in the amount of 83 MW, and by the end of 2014—134 MW.

**Basic challenges to be solved:**

- Power supply backup and electric power quality for shaft-sinking, tunneling and railway loads;
- Fault prevention and performance control.

**Technologies applied:**

- Digital substations;
- Active front ends;
- Synchronized measurement devices;
- Static reactive power compensators.

**Goals and Objectives of Elgaugol AAG Cluster Development**

The objective of the Elgaugol smart grid cluster project is to create the elements of AAG smart energy systems within the pilot areas, and to measure their key technical and economic performance indicators.

**Main issues to be solved within the project implementation are as follows:**

- Development of key design and engineering solutions for smart grid elements creation in the Unified National Power Grid, at the level of substation and control point of substations group.
• Implementation of SES AAG elements based on the state-of-the-art technologies, with results monitoring at each phase.
• Comprehensive testing of engineering solutions for smart grid elements development in various functional modes.
• Assessment of technical and economic performance indicators of proposed innovative solutions compared to traditional ones.
• Issuing recommendations to manufacturers regarding the improvement of technical specifications of equipment used in the project.
• Preparation of recommendations regarding the amendments in existing regulatory documentation and new regulations development.
• Comparative analysis of smart and classical loops of the cluster.

To achieve the goals and objectives set within the project, it is suggested to arrange pilot areas at Prizeyskaya 220 kV Substation, Elgaugol 220 kV Substation, A 220 kV Substation and B 220 kV Substation, with the control centre for substations group being established at Prizeyskaya Substation.

A number of innovative solutions will be implemented at the new facilities. It is suggested to build full-scale and fully functional digital control systems (DCS), RPA and AIMS CEM systems of new generation, based on the process digital bus (IEC 61850-9-2). Bus interfaces will serve as a source of information for the process bus, by transforming instantaneous current and voltage into IEC 61850-9-2 digital flow, and discrete signals into GOOSE messages.

The connection points of 220 kV overhead lines will be equipped with PMU devices.

The plan is to install hardware and software for network monitoring and equipment control in the Control Centre for Substations Group.

**Pilot Areas Arrangement and Key Engineering Solutions Applied at Elgaugol Cluster Facilities**

![Scheme Diagram]

**Scheme**

- Elgaugol 220 kV Substation
- A 220 kV Substation
- B 220 kV Substation
- Prizeyskaya 220 kV Substation
- Control Centre for Substations Group
- Transmission substations control point
- Triplication control of switching group
- PMUs connected to substation devices and failures of local equipment
- Active and adaptive algorithms execution system
Facilities Operation Mode

All equipment of the central control system (CCS) with RPA and AIMS CEM digital systems, intended for AAG smart loops creation, will be installed in parallel with the APCS, RPA and AIMS CEM in traditional format (supporting the substation bus IEC 61850-8.1). This equipment will function in monitoring mode, without any control actions on operating members (only in alarm mode), unlike the traditional systems which cause switch-off in normal operational mode. Thus, CCS with digital RPA and utility metering AIMS CEM systems will not affect the operation of both the primary equipment of a substation, and the equipment of traditional APCS and RPA. The equipment of CCS and traditional APCS and RPA are adjusted similarly. Functioning of both new and traditional devices will be logged for further comparative analysis. The information from CCS and classical APCS will be delivered to the hard- and software complex of Substations Group Management Centre in the form of two parallel flows, for the analysis and comparison of performance of all systems at the substation.

Brief Description of Key Engineering Solutions

Digital System of Substations Control

The proposed solution is based on full and comprehensive use of IEC 61850 standard (sections 8 -1 and 9-2). Use of solutions based on this standard provides a number of considerable advantages, including the following:

- Reduction of capital costs for cable communications, assembly and adjustment;
- Simple integration of all substation systems into a single information environment;
- Information exchange acceleration;
- More precise measurements due to the exclusion of complementary errors;
- Cost saving due to the group automation devices (one device per several connections, e.g., backup protection terminal);
- Reduction of operational costs;
- More reliable operation of substation due to the following:
  - Self-diagnostics of terminals and information networks, with early detection of abnormal operation of equipment;
  - Prevention of unauthorized or incorrect actions of personnel;
  - Use of optic fiber communication lines providing ideal galvanic isolation.

Another significant reason for using IEC 61850 standard is the fact that it is supported by new types of primary equipment, which simplifies the information integration, control and diagnostics.

The main novelty tried in this project is the use of process bus which provides most of the advantages described above.

Process bus is a high-rate medium of data communication, which transfers instantaneous current and voltage measured and transformed into digital format, as well as the positions of switching devices for all control tasks implementation (CCS RPA, electric power metering etc.). The process bus is an optic communication channel providing data transfer in accordance with IEC 61850-9-2 standard; it is installed in the form of Ethernet100BASE-FX network. Combined transformers of current and voltage with digital interface, or bus interfaces connected to traditional metering transformers, serve as a source of data for the process bus. These devices measure instantaneous current and voltage and transfer them via Ethernet in the format according to IEC 61850-9-2.

To collect discrete information and to give control commands, special devices are used, which fix current state of switchgear and other sources of discrete data, transform them into digital form (GOOSE message format according to IEC 61850-8-1), and transfer them to data exchange network (process bus).

Consumers of this information, such as relay protection terminals, connection controllers, power meters, or disturbance recorders, are also connected to the process bus.

To arrange the bus common time, time servers supporting PTP protocol are applied.
Due to the high importance of digital communications system for the operation of entire complex of the cluster subsystems, more stringent requirements have been set to the information safety, including data protection from internal and external threats, protection of each point of potential invasion into digital network, and network traffic filtration.

CCS provides the implementation of all technological and general system functions meeting the requirements of FGC UES and industry-specific regulatory documents. Process functions support is especially remarkable: collection and processing of analog and discrete signals, equipment control, identification of damage location, disturbance recording, electric power quality control etc.

CCS provides the integration of RPA, utility metering system, and PMU subsystem on the base of IEC 61850-8.1.

**Structural Scheme of Pilot Digital Areas at Prizeyskaya 220 kV Substation**

**RPA**

CCS RPA subsystem is based on the comprehensive application of IEC 61850 standard. Microprocessor terminals are integrated to process digital bus in accordance with IEC 61850-9.2 and station bus in accordance with IEC 61850-8.1. RPA system is designed with minimum number of cable communications: information exchange between the RPA terminals is performed in the form of GOOSE messages, analog values are measured by current and voltage transformers and transferred to the terminals by SV flows; on-line control keys are removed from the RPA cabinet and replaced with control commands sent from the CCS operator’s workstation. The set of protection means for the smart loop provides full protection of all power elements of the cluster. At substations A and B the line transformers are protected with a trial solution of HardFiber GE Multilin. For the period of trial operation, the smart loop protection operates in alarm mode with further transition into switch-off mode.

**AIMS CEM**

For commercial energy metering, meters are installed on each connection, which receive the data on instantaneous current and voltage from the process bus in IEC 61850-9.2 format. Having transformed these values into step-by-step increments of power and energy, as well as the basic parameters of
electric grid, the meters transfer the measured data in DLMS format via Ethernet to the Substations Group Management Centre for further processing. At the level of Substations Group Management Centre AIMS CEM server is installed, where measurement data and event logs are visualized and stored and, moreover, balance of power demand is calculated for different metering points; power consumption is forecast for preset points, and data required for commercial calculations of wholesale power market are exported. Furthermore, the access to human-computer interface is made in the form of WEB service, which makes it possible to arrange the workstations of operators in the allocated areas, without using special software.

**PMU**

Control and monitoring of normal and transitional modes of Prizeyskaya—Elgaugol 220 kV transit line are carried out using parametric measurement units (PMU) installed on all inlets of overhead transmission lines connected to the process digital bus.

**Substations Group Management Centre**

Hardware and software complex designed for the Substations Group Management Centre must provide the management of facilities within Elgaugol energy cluster, which includes collection, storage and further processing of on-line and off-line information, control of substations equipment including the equipment of pilot areas at the cluster facilities.

*Completed hardware and software complex for the Substations Group Management Centre must solve the following basic tasks:*

- Operational management of transit substations group;
- Arrangement of the upper level of on-line and off-line process information collection from CCS and APCS at 220 kV transit substations;
- Monitoring and diagnostics of primary smart equipment;
- Collection of information from adjacent systems: PMU, overhead lines monitoring (SmartBall);
- Provision of tools for comparative analysis of the information received from traditional APCS and from CCS;
- Remote control of substation equipment, including collection and analysis of the information received from smart segments of substations;
- Arrangement of information exchange between the Substations Group Management Centre and Amur Grid Management Centre (Blagoveshchensk city).

*A specific feature of the Substations Group Management Centre hardware and software complex is that there are two flows of information:*

- from traditional APCS based on Sprecher and Siemens equipment supplied under the general title of construction;
- from the new generation CCS, i.e. electric power measuring, control, RPA and metering devices operating on the base of process bus.

Therefore, beside traditional tasks solved by SCADA hardware and software at dispatching centres, these hard- and software should provide interaction and comparative analysis of two APCS systems implemented at the cluster facilities. Also, the control of equipment of new-generation digital segments must be limited; the control should be performed only in the alarm mode, without direct effect on switchgear devices.

Since the project goal is extraordinary, the requirements to visualization become higher; the structure of memo pages must simultaneously provide the possibility for systems analysis, not overload the area of visual perception, and provide convenient interface for users.
The objective for development of adaptive automated system of optimal voltage and reactive power control (AASOC) at Elgaugol energy cluster is to ensure automatic maintenance of preset levels of voltage optimal control at the buses of substations within the energy cluster, and, at the same time, to minimize the electric power losses and to improve the quality of electric power under the conditions of changing operation modes and content of the involved equipment at electrically close grid facilities.

Along with CCS, the creation of AASOC at Elgaugol energy cluster form a segment of smart energy system, i.e. active and adaptive grid of Elgaugol energy cluster.

AASOC has a two-level structure. The lower level is formed by substation local systems of automated control of reactive power compensation units installed at the cluster facilities (bus interface, capacitor bank, on-load tap changers for transformers and autotransformers, breakers control automation) which implement the control commands computed at the higher level of the system. The higher level of AASOC is a centralized adaptive system of automated optimal control of voltage and reactive power of Elgaugol energy cluster, which determines optimum levels of voltage and var flows.

**220 kV Overhead Lines Monitoring System**

To control the parameters of overhead transmission lone, the span of the Prizeyskaya A and Prizeyskaya B 220 kV overhead transmission line in the area of crossing over the Zeya river will be equipped with SmartBall Hyundai monitoring system. A controller and workstation for the overhead line monitoring system will be installed in the transit Substations Group Management Centre.

**Proving Ground of Elgaugol AAG Cluster**

Proving ground of Elgaugol AAG cluster will be created for testing the key engineering solutions of the project and for testing the compatibility of equipment by different manufacturers according to IEC 61850 standard. Based on the results of tests, final selection of manufacturers to participate in the project will be made.

**Tested Structure**

Two cells of 220 kV overhead transmission line, with full set of devices of CCS, CCS RPA, AIMS CEM, PMU and local control centre, are formed at the proving ground.
For real modes simulation, it is planned to use a dynamic model of energy system based on RTDS complex. The objective of testing is to determine the equipment suppliers meeting the requirements to compatibility in accordance with IEC 61850 standard; to develop methodologies for pre-commissioning of the complex equipment, to prepare manuals for system maintenance and scheduled audits.

*Elgaugol AAG cluster is a pilot project and has no analogues in the Russian Energy System. The project implementation will require accumulation of front-end solutions in the field of digital technologies and automation, and their application in the substations built within Elgaugol cluster. It is difficult to overestimate the experience gained in the course of design development, testing, putting into trial operation and further maintenance of smart segments; this experience will be useful for equipment designers, as well as design, engineering and service companies. The results of the cluster trial operation will become a basis for regulatory documentation governing the main technical principles of digital control systems development, design, commissioning and operation. Elgaugol AAG cluster project is a starting point for the implementation of solutions related to active and adaptive control; it provides a possibility to compare them to traditional solutions in practice.*

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